# 6.2-6.4 RDT&E Reviews
# 06-08 March 2012
# Stennis Space Center, MS

**Project: Modeling Sensing and Forecasting Ocean Optical Products for Navy Systems**
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# Modeling, Sensing and Forecasting Ocean Optical Products for Navy Systems

## Objectives

Provide naval operations with a real time and forecast characterization of the battlespace used to produce warfare performance surface for ocean optical and visible detection

1. Forecast coastal ocean optical properties including water clarity, horizontal and vertical visibility for visual detection vulnerability and lidar penetration depth (ALMDS).
2. 3D optical volume (nowcast/forecast) derived by assimilating gliders, satellite and ocean models to define the 3d optical structure.
3. Performance surfaces supporting underwater laser imaging systems (AQS/EODES), airborne laser systems (ALMDS), active and passive EO bathy systems, and diver operations (visibility/vulnerability).

## Requirements and Capabilities

CINC OCEN 91-06 Ocean Prediction Models, LITT OCEN 93-06 Hi Res Surface Current Predictions, USMC 93-01 Littoral Sea Environment and addresses needs outlined in the Concept of Operations for Naval Oceanography Support to Expeditionary Warfare

- Predict and forecast the 2D/3D optical environment
- Fusion of environment data for impact assessments
- 4 d coherent picture of the coastal environment
- (Naval Capability Based Assessment for oceanography for 21$^{st}$ Century EXW)  Oct 2009)
- TACMEMO under development for performance  surface for active EO Identification  CNO(N841A) 762-0601; 16 October 2009
- METOC Environment Initial Capabilities Document (ICD) define performance field for MIW imaging system

## FY11/12 Accomplishments/Challenges/Issues

1. Fleet MIW Demonstration/Evaluation of TODS components & AQS-24 Performance Surfaces during Vulcanex 11-1 in Panama City with HM-14, NOMWC, AWSTS,  NSA PC, NSWC PC. (NRL/NAVO Glider Operations) – NGOM Test Bed
2. Transitioned TODS OpCast v2.0 to NP3. VTR/OPTEST Completed.
3. Development and integration of new 3D advection software (BioCast) into TODS Completed / Validation Underway
4. 3D BioCast (v1.0) surface forecast testing/automation completed using multiple satellite and model resolutions:
   - MODIS 1km / RELO-NCOM AMSEAS (NAVO) 3km for MissBight / NGOM test bed – 24 hour forecast at 3 hour time steps. Initial comparisons with OpCast v2.0 (Real-time since Sep. 2011)
   - MODIS 250m / RELO-NCOM chesapeake_miw (NAVO) 500m for Chesapeake Bay – 48 hour forecast at 1 hour time steps. (3 month sequence Sep. 01 – Nov. 28, 2011)
   - HICO 100m / RELO-NCOM chesapeake_miw (NAVO) 500m for Chesapeake Bay – 24 hour forecast at 1 hour time steps. (1 Day)
   - GOCI 500m / RELO-NCOM wpac_2 (NAVO) 3km for Yellow Sea – 7 hour forecast at 1 hour time steps (1 Day) w/ validation

## Funding

| ($K) | FY11 | FY12 | FY13 | FY14 |
|---|---|---|---|---|
| JPSS - cal val | 180 | 200 | 200 | 200 |
| 6.2 Subsurface Optics | 630 | 565 | | |
| 6.2 Algortihm ensemble | 500 | 500 | 500 | |
| **Modeling, Sensing and Forecasting Ocean Optical Products for Navy Systems** | 300 | 150 | 365 | 200 |
| | | | | |
| | | | | |
| | | | | |
| | | | | |

# Modeling, Sensing and Forecasting Ocean Optical Products for Navy Systems

## *Project Schedule With Major Deliverables*

| Tactical Ocean Display System (TODS) | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | FY11 | | | | FY12 | | | | FY13 | | | | FY14 | | | | FY15 | | | |
| | Q1 | Q2 | Q3 | Q4 | Q1 | Q2 | Q3 | Q4 | Q1 | Q2 | Q3 | Q4 | Q1 | Q2 | Q3 | Q4 | Q1 | Q2 | Q3 | Q4 |
| (1) Forecast Optical Properties (OpCast-2D FY11 / BioCast-3D FY12) | | | V | O | | | V | O | | | | | | | | V | O | | | |
| (2) 3D Optical Nowcast (3DOG) w/ AQS-24 System Performance | | | | | | | | | | | | V | O | | | | | | | |
| (3) Exercises / Demonstrations | | | D | | | D | | | | | D | | | D | | | | | | |

Milestones indicate **V**TR panel-accepted and **O**PTEST

OpCast v1.0: 100% complete, OPTEST completed 4QFY11

BioCast v2.0: 60% complete , Planned Transition / VTR  3/4QFY12, Possible delay due to MIW asset / optical glider availability in planned exercise.

3DOG v1.0: 35% complete , Planned Transition / VTR Q4FY13
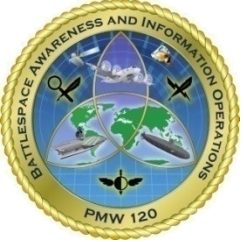
# Modeling, Sensing and Forecasting Ocean Optical Products for Navy Systems
## *Transition Plan Summary*

4.  **SUMMARY CONOPs:** The TODS system and its components will reside with NAVO NP33 automatically producing NRT high resolution integrated oceanographic products to support a variety of Navy missions. TODS will primarily be used to support MIW exercises/operations but also supports a variety of shallow water missions *(NSW, ISR, ASW and EXW)*. TODS currently provides 2D optical forecasts out to 48 hours. Once all the components of TODS are transitioned, it will provide 3D optical forecasts and MIW system performance products out to 48 hours. These products will be provided to the fleet customer via many avenues *(NEP-OC, email, possibly NGDS)*. *POC Kenneth Matulewski (NP33)*

5.  **CAPABILITY REQUIREMENTS BASIS:**
    –   This project supports CNO validated requirements CINC OCEN 91-06 Ocean Prediction Models, LITT OCEN 93-06 High Resolution Surface Current Predictions, USMC 93-01 Littoral Sea Environment and addresses needs outlined in the Concept of Operations for Naval Oceanography Support to Expeditionary Warfare.

6.  **INPUTS:**
    –   Satellite ocean color **imagery** (MODIS-Terra, MODIS-Aqua, MERIS, GOCI, and future JPSS)
    –   physical and optical **glider data** (quality controlled), BSP/AEP data,
    –   numerical **models** (NCOM, RELO)

7.  **OUTPUTS / PRODUCTS:** Outputs will advance NRT high resolution fused oceanographic products to support a variety of shallow water naval missions *esp. MIW*.
    –   a 2D/3D forecast of coastal ocean optical properties for the performance surface
    –   laser imaging systems performance surface (such as the AN/AQS-24)
    –   swimmer performance surface (visibility and vulnerability)
    –   laser system performance surface (eg. ALMDS)
    –   a performance surface to support deployment of active and passive EO bathymetry systems (e.g. CHARTS)

9.  **ACCEPTANCE CRITERIA:**
    –   TECHEVAL at NRL with resulting VTR acceptance at NAVO
        •   TECHEVAL will take place at NRL and be demonstrated during fleet MIW exercises.
            –   Will compare 24 hour forecasts to next day images and profile data not assimilated into TODS to model data.
            –   will include Case II waters.
        •   Validation Test Reports (VTR's) will include validation during real MIW fleet exercises and the Northern Gulf of Mexico Test Bed
    –   Successful OPEVAL at NAVO
        •   OPEVAL will involve install and testing the transitioned software on NAVO systems for a 2 month period and using the system to participate in a fleet exercise.

10. ***OPERATIONS AND MAINTENANCE REQUIREMENTS:***
    •   2 months for OPEVAL and training will be required.
    •   1 FTE will be required to run operationally after transition.
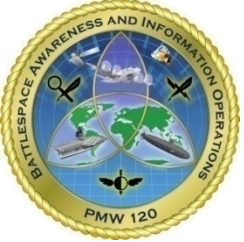
# Outline

- **MIW Exercise Demonstrations / Testing / Evaluation**
  1. VULCANEX 11-1 Panama City, FL (April 2011)
  2. TACDEVEX Arabian Gulf (November 2011) – MIW Assets Pulled – No NAVO Glider
  3. BOLD ALLIGATOR Onslow Bay (February 2012) – MIW Assets de-committed
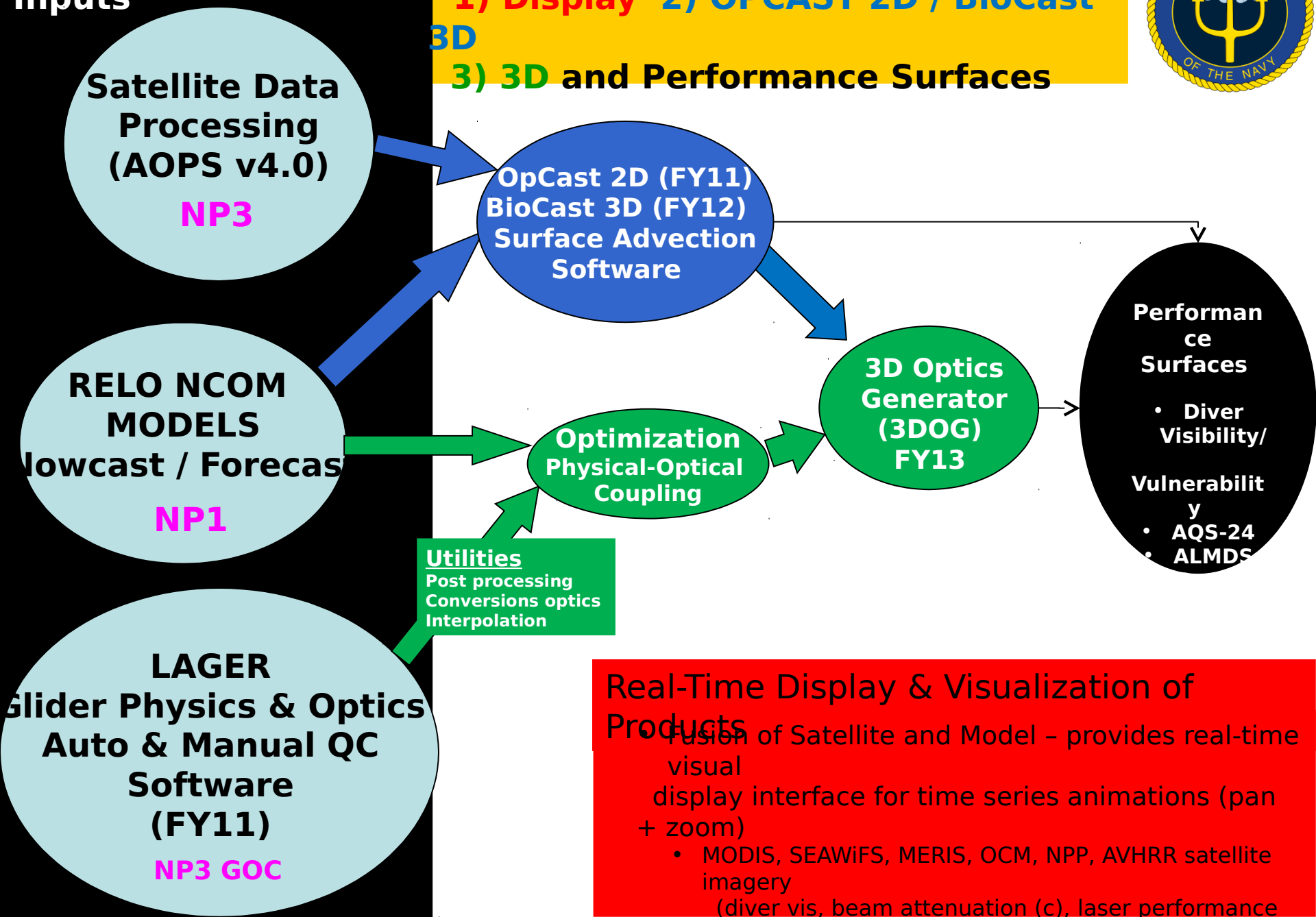  4. HAWKEX (March/April 2012) - Planned
- **Surface Advection Software Upgrade**
  1. Status of BioCast v1.0 (3D Advection Scheme) Upgrade.

# Components of TODS

**NAVO Operational Inputs**

Satellite Data Processing (AOPS v4.0)
**NP3**

RELO NCOM MODELS Nowcast / Forecast
**NP1**

LAGER Glider Physics & Optics Auto & Manual QC Software (FY11)
**NP3 GOC**

OpCast 2D (FY11) BioCast 3D (FY12) Surface Advection Software

Optimization Physical-Optical Coupling

**Utilities**
Post processing
Conversions optics
Interpolation

3D Optics Generator (3DOG) FY13

Performance Surfaces

• Diver Visibility/

Vulnerability
• AQS-24
• ALMDS

Real-Time Display & Visualization of Products
• Fusion of Satellite and Model – provides real-time visual
display interface for time series animations (pan + zoom)
• MODIS, SEAWiFS, MERIS, OCM, NPP, AVHRR satellite imagery
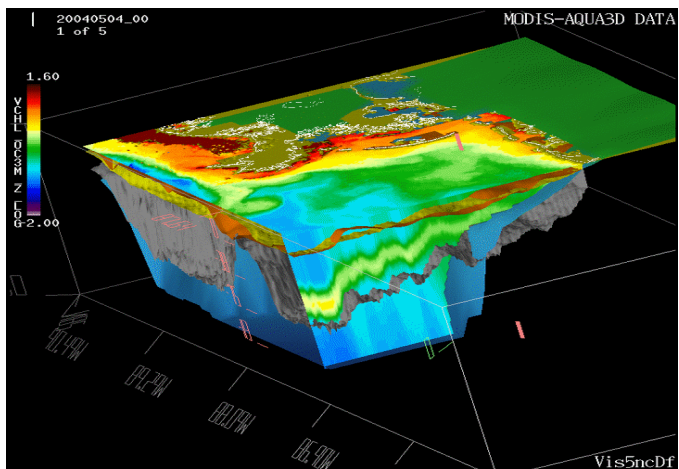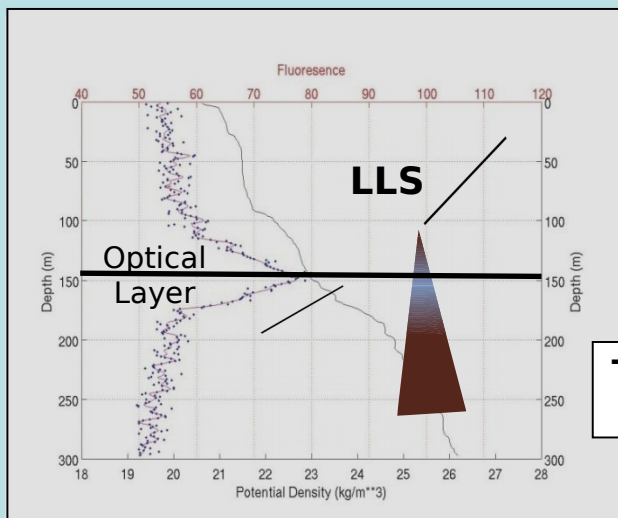(diver vis, beam attenuation (c), laser performance

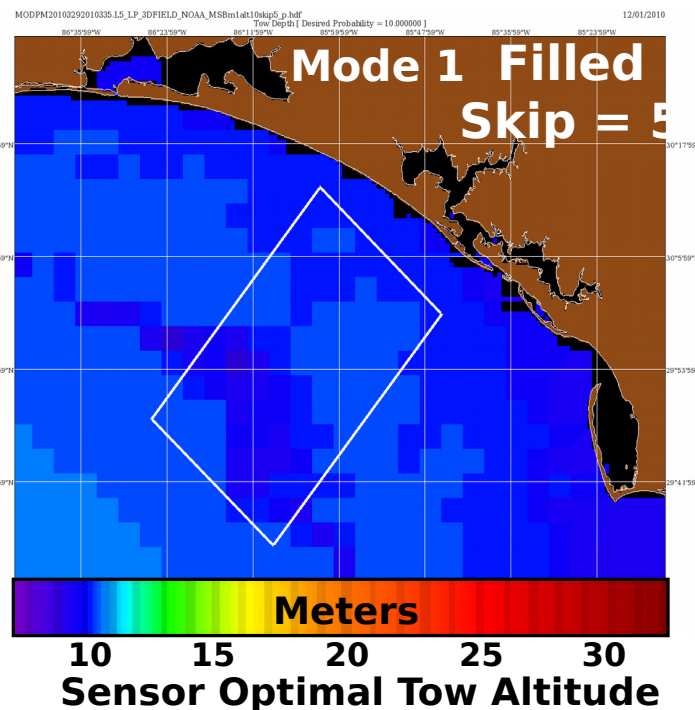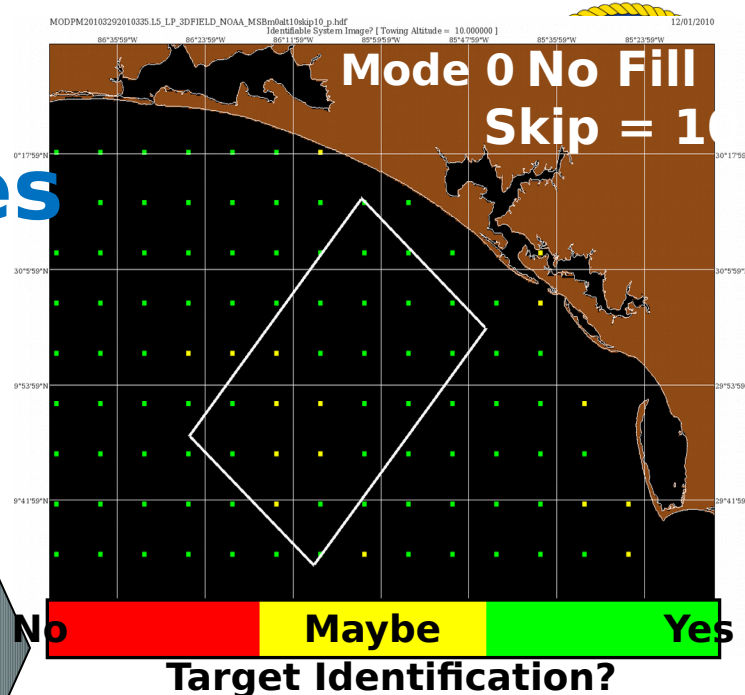# EO/AQS-24
# Performance Surfaces

## Regional Battlespace Characterization
## 3d optical profiles



Performance Model (EODES)



Mode 0 No Fill Skip = 10

| No | Maybe | Yes |

**Target Identification?**



Mode 1 Filled Skip = 5

Meters

5  10  15  20  25  30

**Sensor Optimal Tow Altitude**



LLS

Optical Layer

EODES Point Performance (BSP)

**Target ID?**

No

Maybe

Yes

Tow **Above**/**Below** Optical Layer
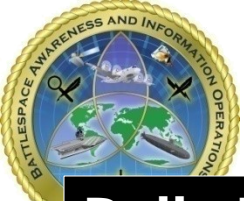
# Vulcanex Glider Operations

## Daily MODIS True Color

Today's Data
**Previous Day's Data**

Mon Mar 21 2011 Mosaic
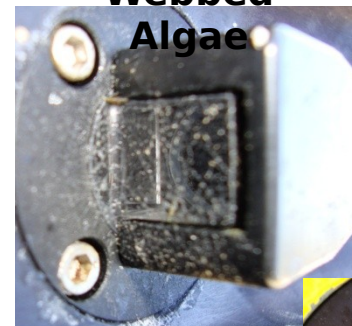
- Deployed by NRL & NSWC on 3/21/11
- Recovered by NRL and USCG on 4/12/11.
- Collected optics data for 23 days
- Covered over 384 km
- Collected over 5,868 Profiles

Glider: sl114
UNCLASSIFIED

Variable: c
Project: GL_VULCANEX
DISTRIBUTION STATEMENT D:

**Bio-Fouling**

**Layers**

**Layers**

**Layers**

MODIS
c_531_qaa
.2 - .5
1/m

X = Bottom

**Webbed Algae**

**Barnacles**

true_color
PanamaCity250 (HMODIS-AQUA-PM)
Version 9 (APS v4.0.14-236-g15403)

Code 7330/Ocean Sciences
Naval Research Laboratory
Stennis Space Center, MS

## Surface Beam-c / Diver Visibility
### 4/06/11 19Z

W — E

| | .1 | .2 | .3 | .4 | .5 | .6 | (1/meters) |

**c**
**531nm**  .8     >1          **meters**
**Diver** 48  24  16  12  9.6  8  6.9
**Vis**    6       <4.8

### 3D Beam-c / Diver Visibility Slice
**(West->East)**
### 4/06/11 19Z

0m

16m

32m

**531nm**  .1  .2  .3  .4  .5  .6  .7  (1/m)
**DiverVis**  .8     >1          **m**
48  24  16  12  9.6  8  6.9
6       <4.8          <5
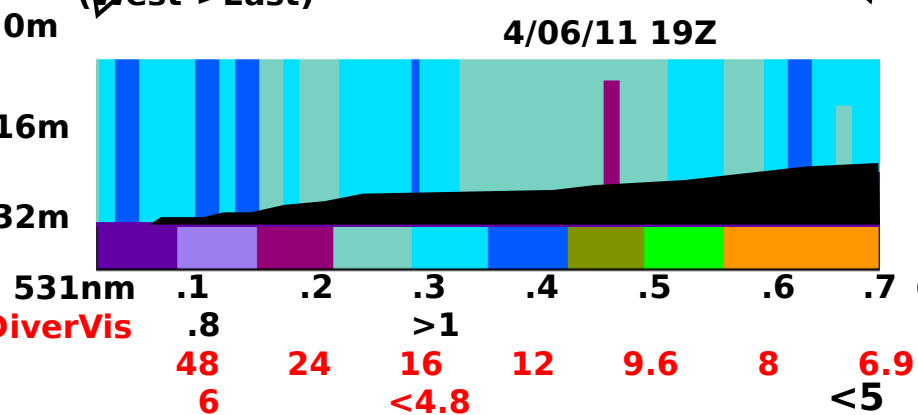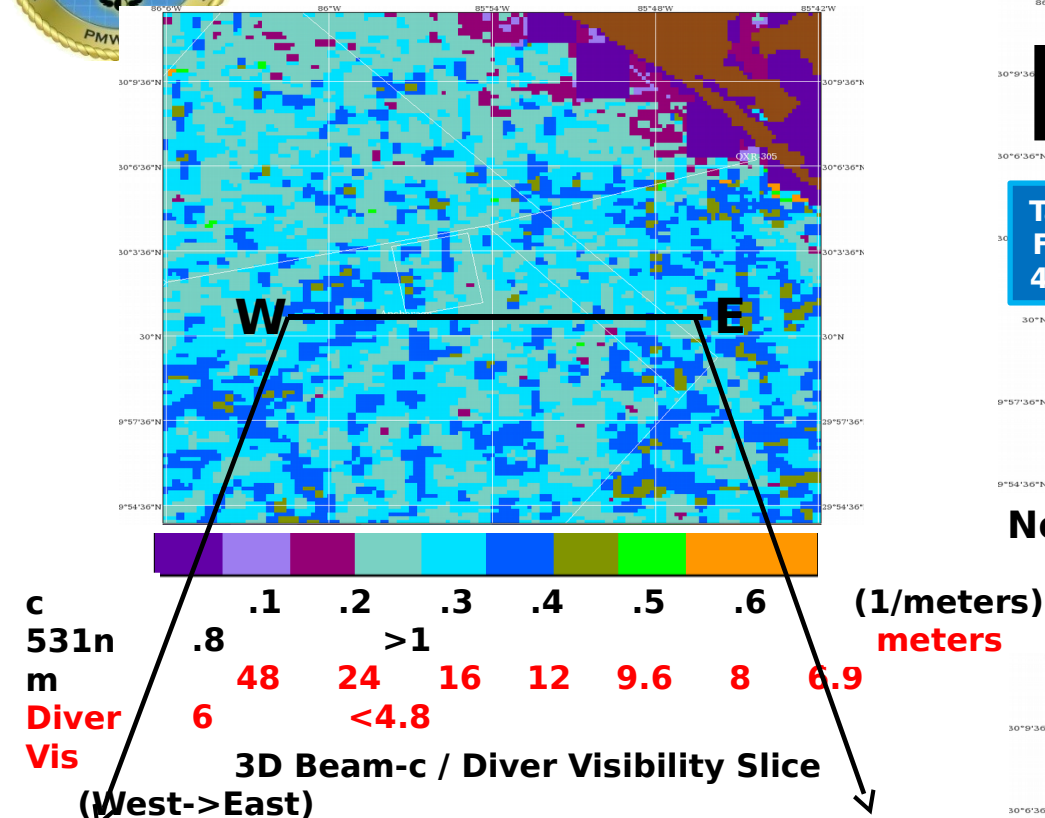
## Target Identification @ 6m/19.7ft Tow Altitude
### 4/06/11 19Z
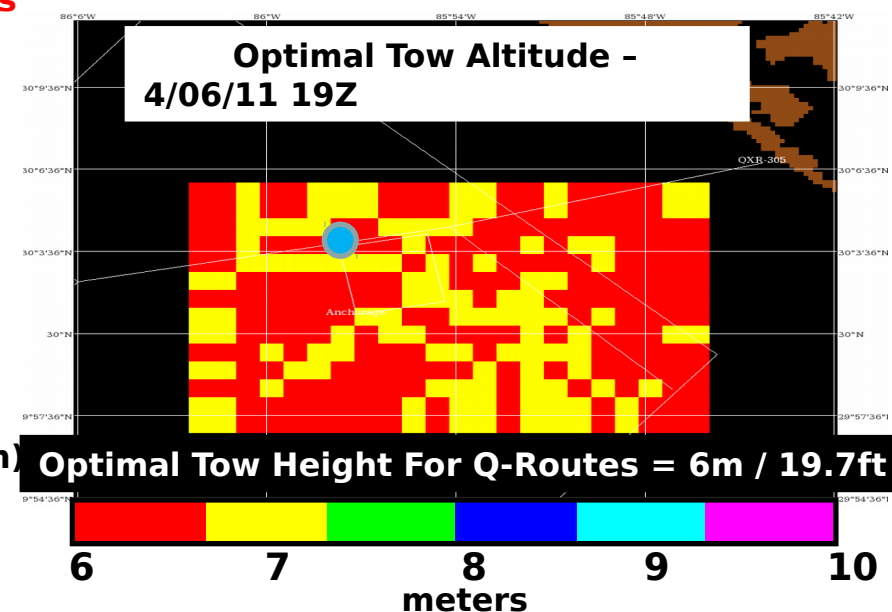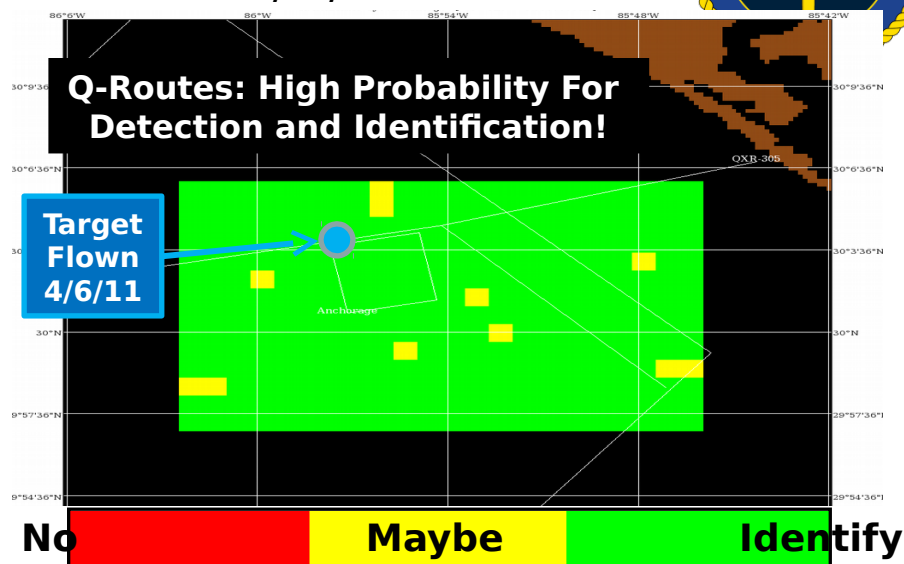
**Q-Routes: High Probability For Detection and Identification!**

**Target Flown 4/6/11**

Anchorage

OXR-305

**No** | **Maybe** | **Identify**

### Optimal Tow Altitude – 4/06/11 19Z

Anchorage

OXR-305

**Optimal Tow Height For Q-Routes = 6m / 19.7ft**

| 6 | 7 | 8 | 9 | 10 |
**meters**

**100% of Mine Targets At Suggested Tow Altitudes Identified!**

### Actual (HM) and Suggested (NRL,NAVO) Tow Heights

| Tow # ID | Date | GMT | Mine Type | HM-14 | NRL | NAVO | DET |
|----------|------|-----|-----------|-------|-----|------|-----|
| 1 YES | 4/6 | 2132 | Mk52 | 20.0 ft | 19.7 ft | 19.7 ft | YES |
| 2 YES | 4/7 | 2238 | Mk52 | 24.0 ft | 22.9 ft | 19.7 ft | YES |
| 3 YES | 4/7 | 2256 | Mk52 | 20.0 ft | " | " | YES |
| | | 2310 | Mk52 | | " | " | YES |

**Same Target**

STEP UPS

STEP UPS
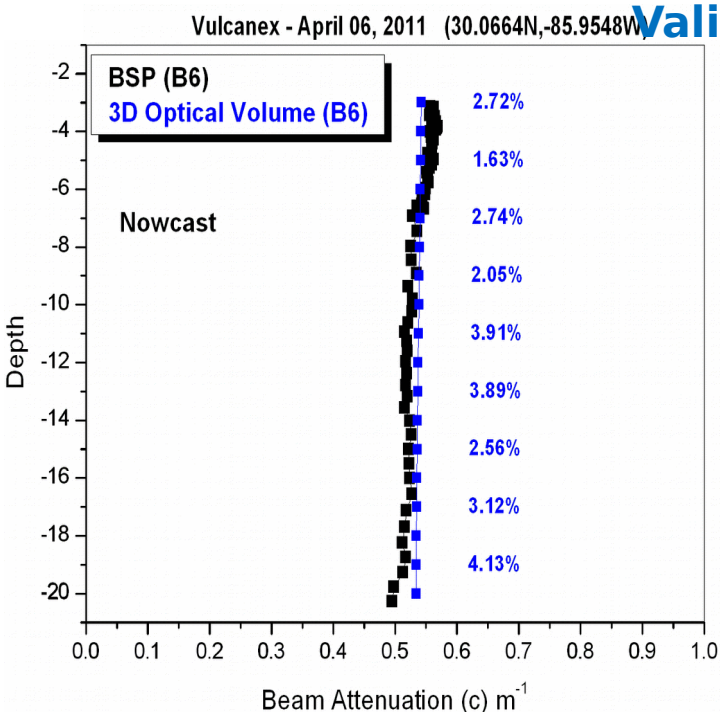
### Validation of 3D Optical Volume
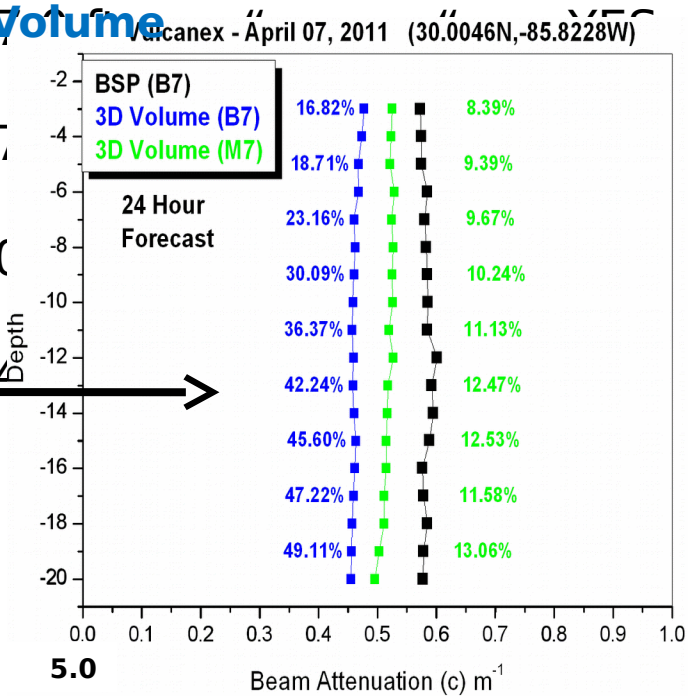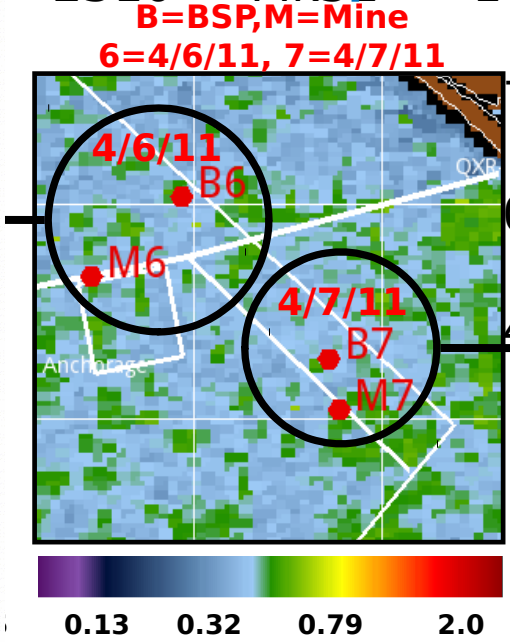


Vulcanex - April 06, 2011  (30.0664N,-85.9548W)

BSP (B6)
3D Optical Volume (B6)

Nowcast

2.72%
1.63%
2.74%
2.05%
3.91%
3.89%
2.56%
3.12%
4.13%

B=BSP,M=Mine
6=4/6/11, 7=4/7/11

4/6/11
B6
M6

4/7/11
B7
M7

0.13   0.32   0.79   2.0   5.0

Vulcanex - April 07, 2011   (30.0046N,-85.8228W)

BSP (B7)
3D Volume (B7)
3D Volume (M7)

24 Hour Forecast

16.82%     8.39%
18.71%     9.39%
23.16%     9.67%
30.09%    10.24%
36.37%    11.13%
42.24%    12.47%
45.60%    12.53%
47.22%    11.58%
49.11%    13.06%

Beam Attenuation (c) m⁻¹
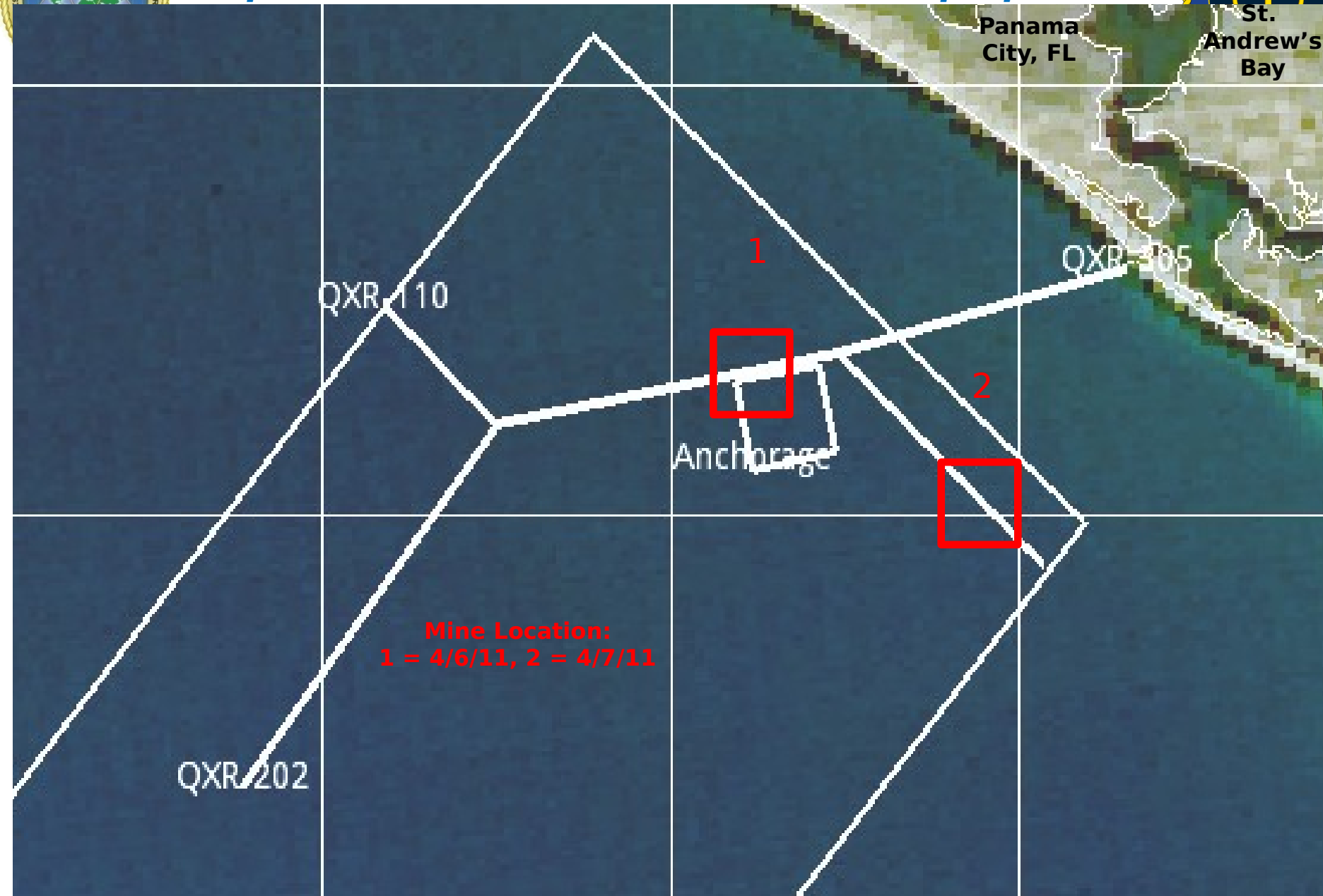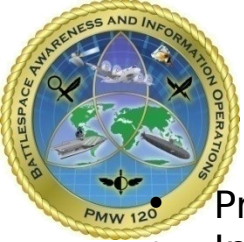
# BioCast 3D Advection

- Preliminary comparisons with OpCast show forecast improvement
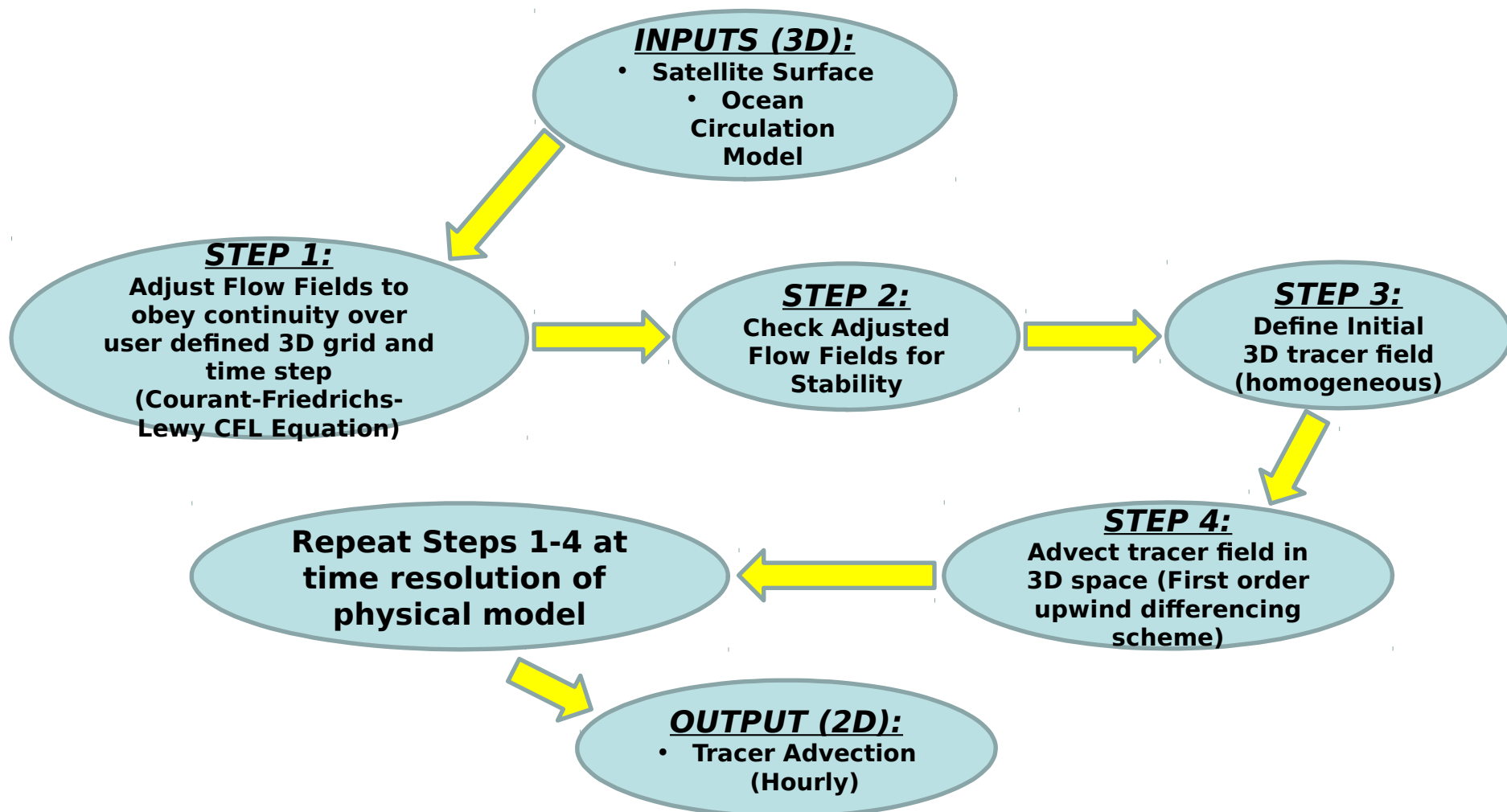- Integration into TODS Complete – Drop in replacement OpCast 2D Advection
- Testing and Validation (VTR) underway
- **Transition to NAVO (NP3) w/ VTR FY 12 (Q3)**

**INPUTS (3D):**
- **Satellite Surface**
- **Ocean Circulation Model**

**STEP 1:**
**Adjust Flow Fields to obey continuity over user defined 3D grid and time step (Courant-Friedrichs-Lewy CFL Equation)**

**STEP 2:**
**Check Adjusted Flow Fields for Stability**

**STEP 3:**
**Define Initial 3D tracer field (homogeneous)**

**STEP 4:**
**Advect tracer field in 3D space (First order upwind differencing scheme)**

**Repeat Steps 1-4 at time resolution of physical model**

**OUTPUT (2D):**
- **Tracer Advection (Hourly)**

NGOM Test Bed
(MissBight)

Imagery Combined
w/ Circulation Models

OpCast/BioCast
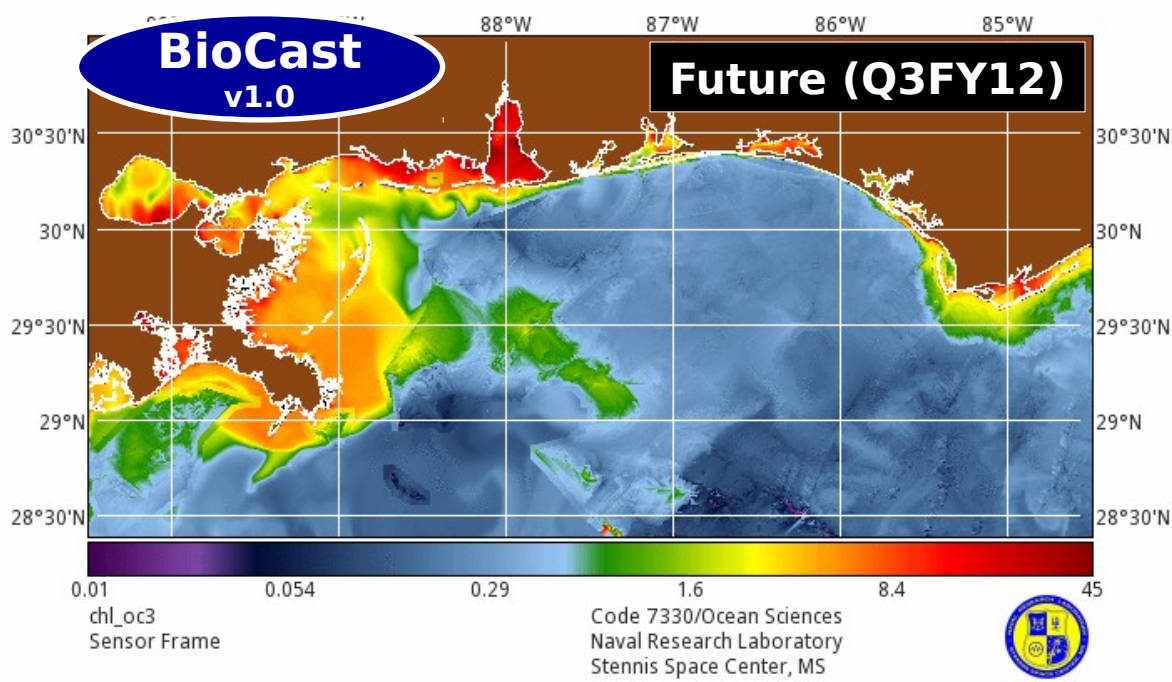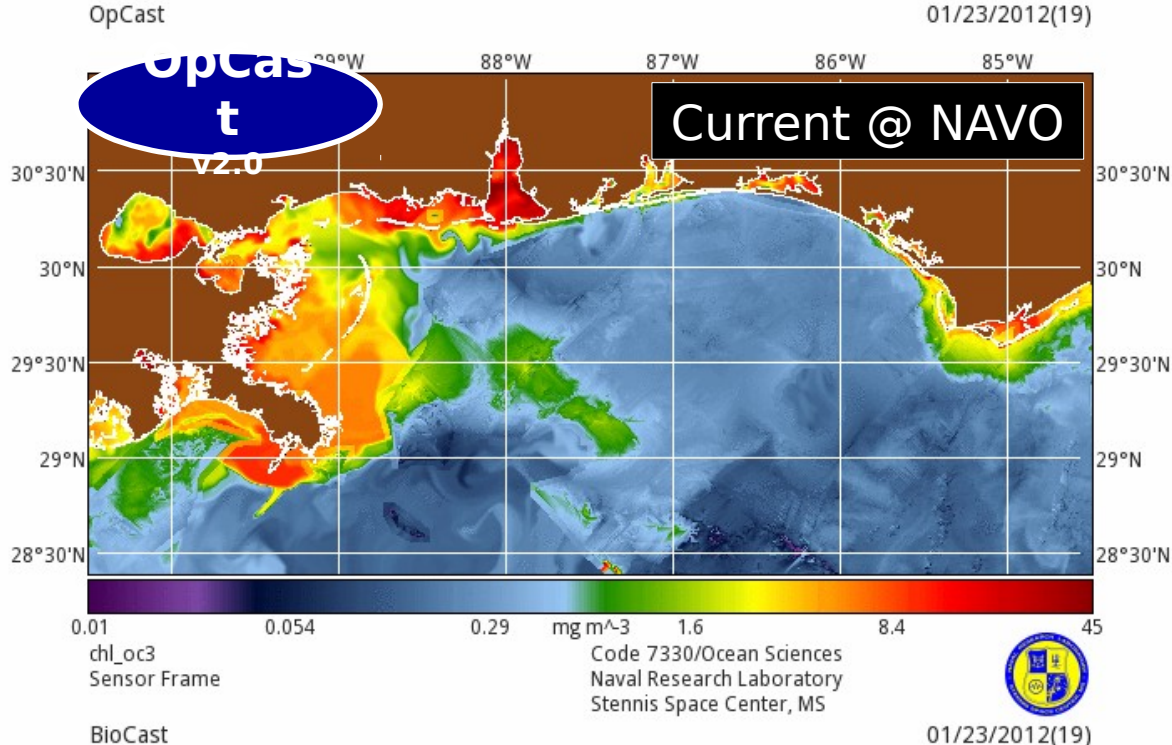Comparison

24 Forecast Animation
@ 3 Hour Time Steps

<u>Satellite:</u> MODIS Chl1km
<u>Model:</u> RELO-NCOM
AMSEAS 3km

Jan 23, 2011

BioCast/TODS
Integration Complete

Running Operationally
@NRL (OpCast & BioCast

GMT
Time

00:15:37 2011

Observed

Seoul,
Korea

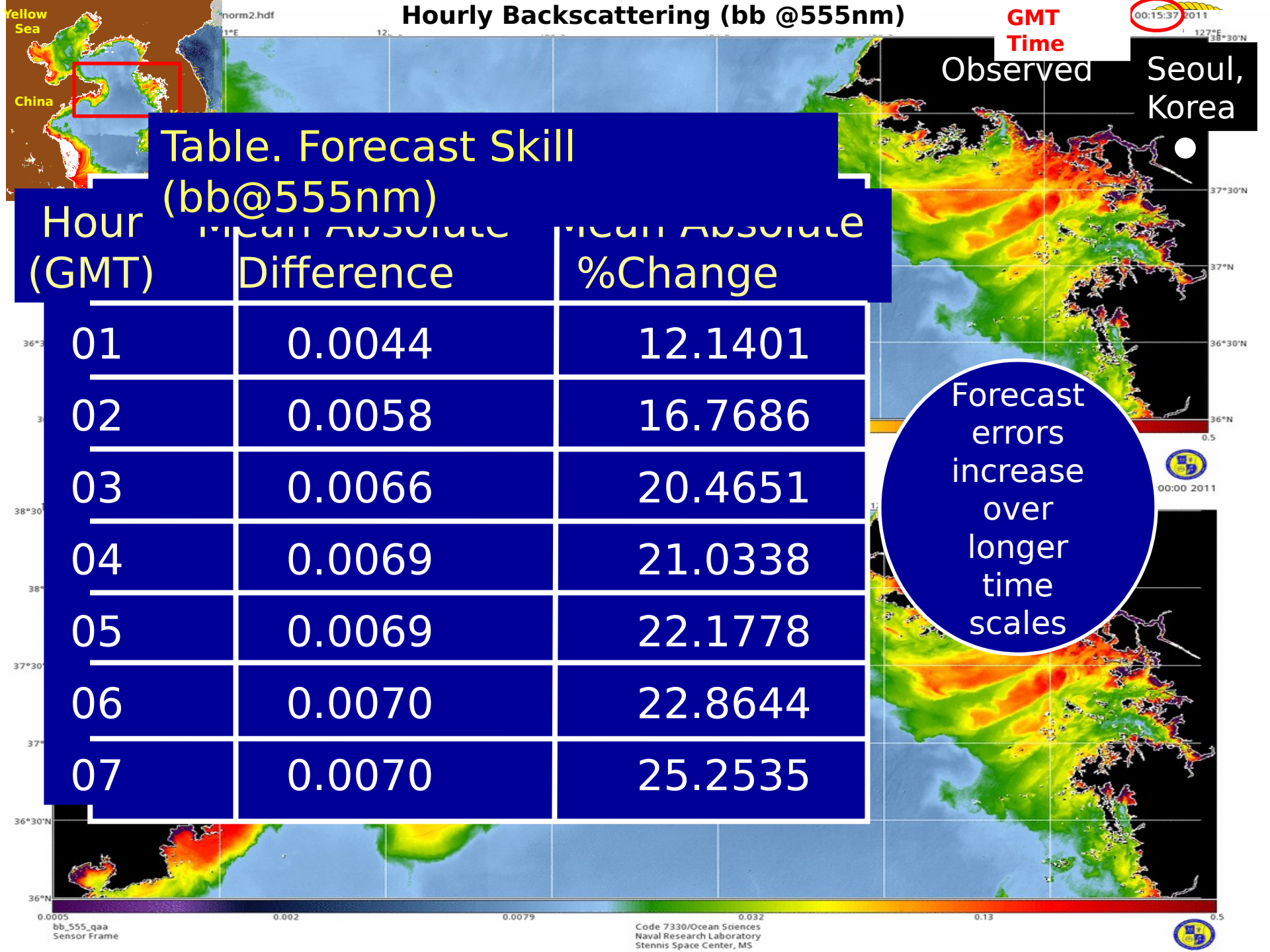## Table. Forecast Skill (bb@555nm)

| Hour (GMT) | Mean Absolute Difference | Mean Absolute %Change |
|---|---|---|
| 01 | 0.0044 | 12.1401 |
| 02 | 0.0058 | 16.7686 |
| 03 | 0.0066 | 20.4651 |
| 04 | 0.0069 | 21.0338 |
| 05 | 0.0069 | 22.1778 |
| 06 | 0.0070 | 22.8644 |
| 07 | 0.0070 | 25.2535 |

Forecast errors increase over longer time scales

00:00 2011

0.0005
bb_555_qaa
Sensor Frame

0.002

0.0079

0.032

0.13

0.5

Code 7330/Ocean Sciences
Naval Research Laboratory
Stennis Space Center, MS

# Summary and Accomplishments

**TODS – Surface Advection Software (OpCast-2D,BioCast-3D)**

- OpCast v2.0
  - Transitioned w/ VTR to NP33 at NAVO
  - OPTEST completed within TODS infrastructure using AOPS v4.0 products
- BioCast v1.0
  - Integration into TODS infrastructure.
  - Initial testing using multiple resolution satellite imagery (100m – 1km) and NAVO
     model data (500m – 3km).
  - Running operationally in real-time (NGOM Test Bed)
  - Transition/Upgrade and VTR scheduled for July 2012 (Q3/4) (In Progress).

**TODS -  End-to-End Validation during MIW Fleet Demonstration (VULCANEX 11-1)**
   - Ocean optical forecast was used for "first time" in HARP MIW exercise for determining
                 tow altitude for AQS-24 (imaging system).
   - Successful forecasting of the EO performance field and validation of mine target
                 detection (100% of mine targets at suggested tow altitudes identified).
   - Squadron requests additional forecast products to improve operational and planning.
                 Received very positive feedback letter from NOMWC (Chief

# 6.2-6.4 RDT&E Reviews
# 06-08 March 2012
# Stennis Space Center, MS
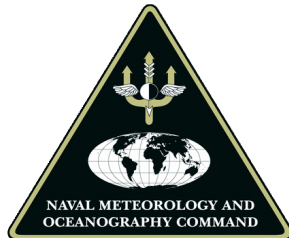
# Questions?

# Modeling, Sensing and Forecasting Ocean Optical Products for Navy

## Project milestone chart submitted for FY13

| Large Scale Prediction: Global Ocean Forecast System (GOFS) Version 3.0 | FY12 | | | | FY13 | | | | FY14 | | | | FY15 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Q1 | Q2 | Q3 | Q4 | Q1 | Q2 | Q3 | Q4 | Q1 | Q2 | Q3 | Q4 | Q1 | Q2 | Q3 | Q4 |
| Major TRL Milestones | | | 6 | 7 | 8 | | 6 | 7 | 8 | 6 | | 7 | 8 | | | |
| 1. Validate BioCast 3D Advection v1.0(2D Output) | | | C | | | | | | | | | | | | | |
| 2. Transition BioCast v1.0 | | | S | C | | | | | | | | | | | | |
| 3. VTR and OPTEST Support | | | | V | O | | | | | | | | | | | |
| 4. Validate 3D Optical Volume Generator (3DOG), update swimmer visibility algorithms, and AQS 24 Performance Surfaces w/ Automatic Optimization of Glider Profiles | | | | | S | - | C | | | | | | | | | |
| 5. Transition 3DOG, Performance Surfaces and SV | | | | | | | S | C | | | | | | | | |
| 6. VTR and OPTEST Support | | | | | | | | V | O | | | | | | | |
| 7. Validate BioCast v2.0 3D Advection w/ integration of 3D Optical Volume (3D Output) | | | | | | | | | S | - | C | | | | | |
| 8. Transition BioCast v2.0 | | | | | | | | | | | S | C | | | | |
| 9. VTR and OPTEST Support | | | | | | | | | | | | V | O | | | |
| 10. TODS Demonstration during Fleet MIW Exercises (BioCast, 3DOG, Performance Surfaces) | | | D | | | D | | | | D | | | | | | |
| 1. Monthly reports | R | R | R | R | R | R | R | R | R | R | R | R | R | R | R | R |
| Budget | | $150 | | | | $365 | | | | $200K | | | | $50K | | |